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OF STUDYING THE MOON

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THE VALUE OF GEOGRAPHIC-GEOLOGIC METHODS OF STUDYING THE MOON

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Summary

The authors discuss the merits of geographic-geologic methods of studying the moon, especially methods based on structural geomorphology and structural and historical geology. It is suggested that lunar research would benefit from the integration of geographic-geologic (comparison with terrestrial material) and astronomical methods of study. Geographic-geologic investigations already carried out in the USSR (A. V. Khabakov, Yu. A. Khodak) and abroad are reviewed, together with the meteoritic theory of the development of lunar relief and structure.

Problems of the origin and evolution of the relief and structure of the moon are increasingly attracting the attention of geologists, astronomers, and geographers. The first attempt to elucidate the structure of the near side of the moon from geological details was that made by the Soviet scientist A. V. Khabakov [1-3], who determined the principal formations of the lunar relief in the order of their appearance. A detailed "geomorphological" study of the relief forms of the near side of the moon has been made by the American geologist Spurr [4]. /460

Various geologic and tectonic schemes of a number of regions of the near side of the moon are presented in the numerous publications of Bülov [5-8], Benes [9-13], Hedervari [14, 15], Mason, Hackman and Shoemaker [16-19], Miyamoto [20, 21], Fielder [22-31], Warner [32-35], McDonald [36], Cameron and O'Keefe [37], Compte [38], Mohacsi [39], Schlicht [40], and other investigators.

Thanks to the photographs obtained in 1959 from a Soviet space probe, the world obtained its first information concerning the far side of the moon [41, 42].

A tectonic scheme of the moon as a whole -- near and far sides -- has been proposed by Yu. A. Khodak [43] on the basis of an analysis of the nature and distribution of the lunar rock formations (ring formations, craters, ranges and chains of ring formations and craters), maria, rills, and clefts. This scheme shows the principal structural elements and the deep fault zones that separate them (cf. article in this issue).

It is quite obvious that at this stage of the investigation, when man has still to set foot on the surface of the moon, the structural "geographic-geologic" approach is indispensable to an understanding of the nature and historical development of the interior, crust, and surface of the moon and the processes of its formation and development as a planetary body. The astronomers alone, without aid from the geologists, have proved incapable not only of solving, but even of formulating the problem of the study of the structural elements of the moon. The present integration of geographic-geologic (comparative) /461
and astronomical methods constitutes the beginning of a qualitatively new era in lunar research.

At present, geographic-geologic studies of the moon are characterized by the exclusive reliance of the geographers and geologists on the results of astronomical observations. In the first place, geologists are obliged to use very accurate photographs of the lunar surface of the type found in the Kuiper atlas [44] and the photographs and drawings of the Wilkins atlas [45] in order to study the individual areas and regions of the moon and obtain a complete picture of both the near and far sides. It is essential that geologists should make direct visual observations of the lunar surface through telescopes with correction of existing photographs (including those made in the invisible part of the spectrum) by means of sketches (the "finest" possible within the limits of resolution of the telescopes) of the details of the lunar relief forms and the relationships between them.

In order to carry out investigations of the structural geography and structural geology of the moon, it is of the utmost importance to obtain the most accurate possible topographic maps (schemes of the relative heights of lunar relief) of the individual areas, maria, and regions and of the entire visible surface of the moon. The structural-geomorphological and structural-geologic interpretation and correction of the corresponding data should be handled by geologists and astronomers collaborating in the process of making visual observations and compiling schematic topographic maps.

Considerable importance attaches to detailed geomorphological investigations, based on photographic methods (including the invisible part of the spectrum), of the nature of the individual ring formations and craters, both large and small, the nature of the clefts, the location of ring formations and craters of different dimensions, form, structure, steepness, and freshness, and the relations between clefts and particular types of ring formations and craters, the relations between different types and systems of clefts and between clefts and series of chains, chains, types of ring formations and craters, etc.

(within the maria as well). The collection and systematization of these geomorphological details must be constantly accompanied by topographic correction.

Our understanding of the surface of the moon can be significantly improved by the structural-geomorphological and structural-geologic interpretation and correction of data on the physical characteristics of the lunar surface and interior -- the albedo, color, temperature, polarization properties, magnetic, spectroscopic, radioastronomical and other data -- these characteristics being taken both individually and in groups. Where groups of characteristics are studied, the changes in the relations between them may be investigated for the individual areas and regions, the maria, and the visible surface of the moon as a whole, and with respect to the nature of the topography, geomorphology and structure, networks of clefts, individual ring formations and craters, series of ring formations and craters, etc. It is very interesting to compare schematic charts of these constants with topographic and structural-geologic maps, for example, Pettengill's radar topographic map of the moon [46].

Since at present the geologists are not in a position to make direct studies of the composition of the lunar rocks (particularly mineralogical and petrographic studies), it is necessary to use data on the physical characteristics of the moon for the purpose of a preliminary determination of the nature and properties of the rocks that form its surface (and perhaps interior) and of their possible distribution. It would be a useful thing to correlate these "petrographic" [1, 47, 48], topographic, geomorphologic, and structural-geologic data with respect to individual areas and regions, maria, and /462
the entire visible surface, as well as with respect to individual chains of ring formations and craters, systems of clefts, the interiors of ring formations, craters, cleft zones, etc. (and within the individual maria).

In order to clarify the origin of the polygonal-ring structures (ring formations and craters), it will be necessary to undertake a detailed structural-geologic investigation of the individual lunar ring formations and craters by visual and other methods of observations and compare them with analogous polygonal-ring structures of the older terrestrial rocks. The chief tasks in relation to the moon are as follows: the study of the nature and shape of the individual ring formations and craters and their relationship to clefts or systems of clefts, the nature and the forms of chains of ring formations and craters, the orientation of their long axes* along chains, clefts or

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*Here mention should be made of the work of M. M. Shemyakin [49] and Fielder and Jordan [30].

systems of clefts, rills, mountain ranges, etc. (including within the maria); elucidation of the polygonal-ring nature of the structure of ring formations and craters, the structural and other relations among individual ring formations and craters and individual parallel or intersecting chains of ring formations and craters, the different degrees and stages of superposition, the neighborhoods of individual ring formations and craters both inside and outside chains; clarification of the relations between the polygonal-ring structures of the ring formations and craters that apparently take the form of unique grabens (polygonal-ring masses that have subsided between faults) and topographic and other data (petrographic, physical, etc.). The material and conclusions relating to the polygonal-ring structures of the moon will greatly assist our understanding of analogous ancient terrestrial structures masked in the course of geological history.

On the basis of the areas of investigation listed above, scientists are now making geologic and hictorico-geologic analyses to distinguish the principal structural elements of the "continental" massifs, the zones of marine depressions, the larger individual features of these massifs and depressions and the deep breaks that separate them, the order of deposition and superposition from ancient times to the present day, the laws of development of the individual regions, and the general laws of development of the lunar crust and the moon as a planetary body.

The Soviet literature contains descriptions of two attempts to make structural-geologic and historico-geologic analyses of the moon: that of A. V. Khabakov [1-3], in relation to the near side, and that of Yu. A. Khodak [43], in relation to both sides of the moon. Both these investigators incline toward a common conclusion concerning the block structure of the moon, the polygonality of its larger "continental" and "marine" structural elements. The polygonality of the contours of the lunar maria has been noted by V. G. Fesenkov [50] and a number of other astronomers. Yu. A. Khodak emphasizes the important part played in the geologic development of the moon and the formation of its crust by the systems of deep fault zones, regions of considerable tectonic activity, along which the most intense formation of polygonal-ring structures, the differential upheaving and subsiding of blocks of various shapes and sizes, the formation of grabens and horsts, clefts, rills, etc., took place.

The block structure of the lunar crust, which, apart from on earth [51], is also found on Mars [52], is further evidence of the general law of development of the solid crust of the planets of the terrestrial group. The study of the block structure of the lunar crust with its abundance of polygonal-ring formations will prove of great value in the interpretation of a number of laws of the earth's crust, particularly of its lower (more ancient) part and the water-filled oceanicic and marine basins, which to a large extent are inacces- /463 sible to direct observation.

The above approach to the study of the moon and the origin of its relief and the geomorphological and structural forms of its crust and interior is diametrically opposed to the so-called meteoritic approach, which seeks to explain the lunar relief in terms of meteoritic bombardment [53, 54]. We shall not enter into a fruitless (at least until the proposed structural geographic-geologic investigations of the moon have been made) discussion, but make use of all that is valuable in the observations of B. Yu. Levin [53, 54] and other partisans of the meteoritic theory concerning the role of intense cosmic bombardment of the moon after its formation (as a planetary body). At this point we shall merely make a few comments of a fundamental nature concerning the "meteoritic hypothesis."

From Levin's argument [53, 54] it follows that immediately after the formation of the moon as a planetary body, when the moon, like all the other planets of the terrestrial group, had collected practically all the solid matter existing in the region of its orbit, there began to develop the "meteoritic" relief that we now see in the form in which it has congealed after hundreds of millions, if not billions (up to 4 billions) of years. According to Levin, the intense meteoritic bombardment of the moon, which formed the lunar relief which we now observe, continued even after the swarm of particles, from which the moon must have been composed, was exhausted.

The partisans of the "meteoritic" hypothesis, without analyzing the evidence indicating a regular and ordered distribution of the relief forms and structural elements of the moon, reject all that is now being done by the numerous specialists (geologists, astronomers, geographers, geophysicists) in the USSR, Czechoslovakia, Hungary, the United States, England, Japan, and other countries working, from different angles, on the problem of the formation of the lunar relief.

This one-sided approach to the question of the development of the relief and structure of the moon can only lead to an impasse and is incapable of reaching a real solution. Only by using the same data to compile the various schematic maps proposed above for analysis and interpretation can the problem finally be solved.

An important and interesting aspect of this subject is the effect of the rotational and orbital motion of the moon on the formation of its structure (including, of course, the relief as its surface expression) and the systems of deep fault zones during the process of its geologic development. Analogous unsystematic investigations relating to the earth have already been published [55-58].

In conclusion, it should be stressed that without the collaboration of geologists it will be impossible to solve the problem of the origin of the lunar relief and structure and the laws of their distribution, or to compile topographic, geographic, and geologic -- selenologic -- charts and maps worthy of modern science.

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BIBLIOGRAPHY

1. Khabakov. A. V. in the collection "Luna" (The Moon). Fizmatgiz, p. 241, 1960.
2. - - - . Ob osnovnykh voprosakh istorii razvitiya poverkhnosti Luny (The Chief Problems of the Evolution of the Lunar Surface). Geografgiz, 1949.
3. - - - . in the collection "Iskusstvennyye sputniki Zemli" (Artificial Earth Satellites), No. 9. Academy of Sciences USSR Press, p. 52, 1961.
4. Spurr, J. Geology Applied to Selenology. Pennsylvania, 1945.
5. Bülov, K. Geologie, H. 6/7, S. 565-609, 1957.
6. - - - . Wiss. Z. Univ. R., H. 1, 1959.
7. - - - . Raketentechn. u. Raumfahrtforsch., 4, No. 3, p. 93-97 1960.
8. - - - . Forsch. u. Fortschr., 35, No. 8, 225, 1961.
9. Benes, K. Risé hvezd, 40, No. 11, 1959.
10. - - - . Tr. Gorn. In-ta (Transactions of Mining Institute), Ostrava, No. 5/6, 1960.
11. - - - . Izv. AN SSSR, ser. geol. (Bulletin of the AS USSR, Geology Series), No. 11, 50, 1962.
12. - - - . Risé hvezd, 41, No. 8, 153, 1960.
13. - - - . Risé hvezd, 41, No. 11, 213, 1960.
14. Hedervari, P. Magyar fiz. folyóirat, 8 No. 4, 261, 1960.
15. - - - . Magyar fiz. folyóirat, 9, No. 4, 251, 1960.
16. Mason, A. Hackman, R. Bull. Geol. Soc. America, 71 No. 12, pt. 2, 2103, 1960.
17. Shoemaker, A. & Hackman, R. in the collection "Novoye o Lune" (New Facts about the Moon). Academy of Sciences USSR Press, p. 220, 1963.
18. Mason, A. Hackman, P. Symp. No. 14 Intern. Astron. Union, the Moon, p. 301, 1962.
19. Shoemaker, A. Hackman, R. Bull. Geol. Soc. America, 71, No. 2, pt. 2, 2112, 1960.
20. Miyamoto, S. Planet and Space Sci., 2, No. 4, 256, 1960.
21. - - - . Contribs. Inst. Astrophys. and Kwasan Observ. Univ. Kyoto, No. 96, 6, 1960.

22. G. Fielder. Sky and Telescope, No. 19, 334, 1960.
23. - - - . Monthly Notices Roy Astron. Soc., 123, No. 1, 15, 1961.
24. - - - . Planet. and Space Sci., 5, No. 4, 286, 1961.
25. - - - . Planet. and Space Sci., 8, No. 1, 1961.
26. - - - . Observatory, 81, No. 923, 140, 1961.
27. - - - . J. Brit. Astron. Assoc. 66, No. 341, 1957.
28. - - - . Nature, 193, No. 4812, 258, 1962.
29. G. Fielder, T. Kiang. Observatory 82, No. 926, 8, 1962.
30. G. Fielder, C. Jordan. Planet. and Space Sci., No. 9, 1962.
31. G. Fielder, B. Warner. Planet and Space Sci., No. 9, 1962.
32. B. Warner. Publs. Astron. Soc., Pacif., 73, No. 434, 349, 1961.
33. - - - . J. Brit. Astron. Assoc., 71, No. 8, 388, 1961.
34. - - - . J. Brit. Astron. Assoc., 71, No. 8, 104, 1961.
35. - - - . Planet and Space Sci., 5, No. 4, 283, 1961.
36. McDonald, G. Planet and Space Sci., 2, No. 4, 249, 1960.
37. Cameron, W., O'Keefe, J. Astron. J., 66, No. 7, 280, 1961.
38. Compte, P. Urania 43, No. 248, 199, 1958.
39. Mohacsi, B. Magyar tud. akad. Mat. és. fiz. tud. oszt. kölz., 10, No. 4, 421, 1960.
40. Schlicht, O. Bull. Geol. Soc. America, 71, No. 12, pt. 2, 2111, 1960.
41. Atlas Obratnoy storony Luny (Atlas of the Far Side of the Moon). Academy of Sciences USSR Press, 1960.
42. Lipskiy, Yu. N. in the collection "Iskusstvennyye sputniki Zemli", No. 9, Academy of Sciences USSR Press, p. 3, 1961.
43. Khodak, Yu. A. Paper read at the Fourth Conference on Problems of Astrogeology, Leningrad, p. 40, 1962.
44. Photographic Lunar Atlas. Edited by G. Kuiper. The University of Chicago, 1960.
45. Wilkins, H. Moon Maps. The Macmillan Company, 1969.
46. Pettengill, G. Proc. I. R. E., 48 (5), 933, 1960.
47. Sharonov, V. Astron. zh. (Astron. Journal), 31, No. 5, 442, 1954.
48. Haynes, C. Mines Mag., 52, No. 1, 26, 1962.
49. Shemyakin, M. M. Byulleten'. VAGO (Bulletin All-Union Astronomical and Geodetic Society), No. 30 (37), 33, 1962.
50. Fesenkov, V. G. in the collection "Problemy evolyutsii Zemli i planet" (Problems of the Evolution of Earth and the Planets), No. 5, Academy of Sciences Kazakh SSSR Press, p. 19, 1951.
51. Peyve, A. V. in the collection "Struktura zemnoy kory i deformatsii gornykh porod" (The Structure of the Earth's Crust and the Deformation of Rocks). Academy of Sciences USSR Press, p. 67, 1960.

52. Katterfel'd, G. N. Izv. Vses. geogr. o-va (Bulletin of the All-Union Geographic Society) Vol. 91, No. 272, 1959.
53. Levin, B. Yu. Byulleten' VAGO, No. 30 (37), 6, 1962.
54. Levin, B. Yu. & Ruskol, Ye. L. in the collection "Voprosy kosmogonii" (Problems of Cosmogony), vol. 8, Academy of Sciences USSR Press, p. 109, 1962.
55. Katterfel'd, G. N. Lik Zemli i yego proiskhozhdeniye (The Face of the Earth and Its Origin). Geografizdat, 1962.
56. Stovas, M. V. & Usenko, D. N. Izv. AN SSSR, ser. geol. No. 11, 101, 1962.
57. Stovas, M. V. Geogr. sb. (Geographical Collection), No. 15, Academy of Sciences USSR Press, p. 29, 1962.
58. Chang Wen-yu. Scientia Sinica, 10, No. 3, 361, 1961.

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